ORIGINAL ARTICLE

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Radiation in the orthopedic operating theatre

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Objective: The aim of the study was to determine the amount of radiation exposure in the orthopedic operating theater, to show that the radiation dose was decreased with distance from the tube, and to inform personnel about protective measures.

Methods: Ionised radiation was measured in the orthopedic operating theater where fluoroscopy was used between 18 February 2014 and 02 June 2014. Four dosimeters were placed at the head and foot of the operating table and at 200 cm from those areas at a height of 60 cm vertical to the floor.

Results: At the end of 104 days, the total values were determined as 90.5 mrem at the foot of the table, 68.17 mrem at the head of the table, 7.5 mrem at 200 cm from the foot of the table, and 5.17 mrem at 200 cm from the head of the table. A significant decrease was observed in the values determined at a distance from the radiation source.

Conclusion: The rate of radiation determined in the dosimeters decreased when distance from the radiation source increased. During the use of fluoroscopy in orthopedic surgery, the wearing of lead aprons, neck protectors, and glasses, in addition to maintaining a distance from the tube, will reduce the radiation exposure of individuals.

Keywords: Fluoroscopy; ionised radiation; orthopedic operating theater.

Since the introduction of the X-ray by Roentgen in 1895, it has been increasingly used in medicine.[1] As C-arm fluoroscopy provides real-time imaging of the skeletal system, it is frequently used in orthopedic surgery, increasingly in combination with minimally-invasive surgery, for fracture reduction and the visualization of orthopedic implant placement.[2,3] However, the widespread use of fluoroscopy exposes not just the surgeon but also the anesthesia team, nurses, auxiliary staff, and the patient to the harmful effects of ionised radiation.[4–6] During fluoroscopy, ionised radiation has been observed to disseminate from the tube in all directions.[7] In standard fluoroscopy, it has been reported that the patient is directly exposed to radiation at a dose of 12–40 mSv/min.[8] Even at doses as low as 0.001 rad, radiation is known to be carcinogenic and to have a negative effect on the skin, eyes, gonads, and blood cells.[9] Tse et al.[10] and Mastrangelo et al.[11] have reported increased incidence of thyroid cancers in orthopedists. There are data that HIV Type I replication activation and lens damage are responsible for ionised radiation.[12]

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The annual cumulative dose of radiation should be a maximum of 20–50 mSv, as reported by the American National Council for Radiation Protection (NCRP) and the International Council for Radiation Protection (ICRP). These values have been reduced over the years as the long-term negative effects of radiation have been seen.[13] During surgical procedures requiring the use of fluoroscopy in the orthopedic operating theater, all healthcare personnel and patients are exposed to ionised radiation. Various precautions have been reported to protect against the harmful effects of ionised radiation, including the use of lead aprons, neck guards to protect the thyroid, special glasses, the use of a scopy technician, an experienced surgical team, and maintaining a distance from the scopy tube.[2]

The annual safe radiation doses as declared by the ICRP are 20 mSv for the whole body and 500 mSv for the hands.[14] Through the placement of dosimeters at 4 different points in the operating theater, the aim of this study was to determine the cumulative and per case dose of radiation during orthopedic approaches made with fluoroscopy. The hypothesis of the study was that the amount of radiation exposure would decrease inversely with distance from the fluoroscopy tube.

Patients and methods

Approval for the study was granted by the Local Ethics Committee of Dr. Lütfi Kırdar Kartal Training and Research Hospital. A total of 284 orthopedic operations were conducted over 71 working days in the 104-day period of 18 February 2014–02 June 2014. In 128 operations, C-arm fluoroscopy imaging was performed. In these operations, surgery was applied to the lower extremities in 101 cases, to the spine in 10 cases, and to the upper extremities in 17 cases. Of the 101 lower extremity surgeries, 45 were in the hip region (proximal femoral nailing in 35 and dynamic hip nailing in 10), 30 were femoral nailing or biological plating, and 26 were nailing or minimally invasive plating. Of the 17 upper extremity surgeries, 10 were closed reduction and pinning for pediatric supracondylar humerus fracture and 7 were open reduction and osteosynthesis with plate for distal radius fractures. Imaging was applied 5,552 times with fluoroscopy and a total of 43,375 images were recorded.

A total of 73.397 min of imaging was performed, with a mean time measured of 34.52 secs per case. To measure the source of the fluoroscopy radiation in the operating theater, 4 optically stimulated luminescence (OSL) dosimeters were used (Radkor, Ankara, Turkey). Dosimeter 1 was placed below the foot end of the operating table, dosimeter 2 was placed below the head end, dosimeter 3 was placed on the wall at a height of 60 cm (200 cm from the foot end), and dosimeter 4 was placed on the wall at a height of 60 cm (200 cm from the head end). The aim when defining the area was to define the amount of ionised radiation exposure in the locations of the anesthesia and surgical team.

The dosimeters were placed in the areas where radiation passed through, and cotton radiolucent plaster tape was used to secure the dosimeters (Cansın-fix-Kocaeli, Tıbbi Esnek Plaster Surgical Elastic Plaster). The study was completed using the same fluoroscopy devices throughout the period of 104 days (Genoray Am.Inc. Performance C-Arm - ZEN–7000 Performance Standart of C-Arms powerful output: 120 kV/20 mA, Stylish Touch Screen Operation Panel, Convenience-Flexibility: 45° overcast 30″ + free space, 120 v power input).

At the conclusion of the study period, the dosimeters were placed in protective cases and sent to the relevant center for the evaluations to be performed (Epsilon Landauer full body dose Hp,[10] Dozimetri Teknolojileri San. ve Tic. A.Ş., Şişli, Istanbul).

Results

At the end of 71 working days, values of 9.05 mrem were found in dosimeter 1, 68.17 mrem in dosimeter 2, 7.5 mrem in dosimeter 3, and 5.17 mrem in dosimeter 4. The amount of daily radiation was determined as 8.70 microSv, 6.55 microSv, 0.72 microSv and 0.50 microSv in dosimeters 1–4, respectively. The mean monthly radiation doses were 0.26 mSv, 0.20 mSv, 0.02 mSv, and 0.01 mSv in dosimeters 1–4, respectively. The highest level of radiation was found at the foot end of the operating table and the lowest level at 200 cm from the head end (Table 1).

Table 1. The daily, monthly and total radiation amounts of the 4 dosimeters.

No	Dosimeter ID	Placement date	Measurement reading date	Dose (mrem)	Daily (microSv)	Monthly (mSv)
1	XA02250637A	18.02.2014	03.06.2014	90.5	8.70	0.26
2	XA02250655C	18.02.2014	03.06.2014	68.17	6.55	0.20
3	XA02429346C	18.02.2014	03.06.2014	7.17	0.69	0.02
4	XA025843753	18.02.2014	03.06.2014	5.17	0.50	0.01

Discussion

The results of this study, in which ionised radiation in the operating theater was measured by placing dosimeters at different points of the operating table and surroundings, showed that the amounts of radiation were below the maximum values declared by the ICRP and NCRP. In addition, a significant drop in the amount of radiation was observed at a distance of 200 cm from the surgical field, supporting the hypothesis of this study.

The Radiation Absorption Dose (rad) is defined as 1 rem = 1 rad in mammals; 100 rad = 100,000 mrem and 100 mrem = 1 mSv.[8,15] According to the American Nuclear Research Society, the annual amount of radiation to which a person can be safely exposed is 6.2 mSv/year, with the absolute maximum annual dose being 50 mSv/year. The lifetime maximum dose is between 500 mSv and 4,000 mSv. As an example, a single lung radiograph produces 0.1 mSv, a lung CT scan produces 10 mSv, and cigarette smoking at 1.5 packets/ day produces 13 mSv/year. These results are useful for comparison with the amount of exposure in the operating theater.[16] The ICRP has defined acceptable dose limits for radiological protection. According to the latest ICRP guidelines, the annual 50 mSv did not exceed the mean 5 year occupational dose limit. The equivalent organ doses are 150 for eye lens mSv, 500 mSv for skin, and 500 mSv for hands and feet.[14,17]

Personnel in the orthopedic operating theater are affected by radiation in 3 ways: direct, reflection, and leakage. The leakage effect is related to the use of the fluoroscopy device, and reflection is from the patient's body or is created by transfer from parts of the operating theater.[18,19] Epidemiological and experimental studies have shown that exposure to even small doses of radiation creates the risk of solid organ cancers and leukemia development.[9,11,13,20,21] Associated with this, in developed countries, annual radiation exposure of more than 50 mSv is not permitted for those working in health centers or nuclear power stations.[13] The principle directing this current study was to determine the radiation dose in the orthopedic operating theater and to serve as a reminder of the precautions that should be taken. Although the routine radiation measurement results to date in our operating theater indicated low levels, this is not a reason for personnel to feel safe. This study can be considered important in terms of providing a basis for more detailed future research.

In a study by Ismail et al.,[22] under operating theater conditions, those most exposed to radiation were shown to be the anesthesia assistants to the doctors, followed by orthopedists, and urologists. According to the results of the current study, the areas in which the orthopedist is working (dosimeter 1 and dosimeter 2) were found to have a higher amount of radiation than the anesthesia field. Although the radiation dose appears safe because of the rotating working pattern of surgeons, when the cumulative effect is considered in operating theaters which are always used by the same auxiliary staff and anesthesia team, the auxiliary staff and anesthesia team could experience greater negative effects. Thus, in this case, one must take the necessary precautions against radiation in areas where fluoroscopy is used.

There are measures which can be taken to protect against the negative effects of radiation. The most important of these is maintaining distance from the fluoroscopy tube, wearing lead aprons, wearing neck protectors for the thyroid, wearing protective glasses, having a surgical team that is experienced in the surgical technique (open and minimally invasive) and using a scopy technician.[1,10,18,23,24] Perhaps the most important is the provision of specific periodic training to the surgical team related to radiation risk and protection. In a study by Khan et al.,[25] it was reported that new surgeons working in orthopedics and trauma were not aware of the negative effects of ionised radiation or protection methods. It is vital that we do everything possible in our working environments to protect ourselves from exposure to radiation of even the smallest dose.

Maintaining a distance is one of the best methods. Mehlman et al.[15] demonstrated that a distance of 1.5 m was sufficient to reduce the exposure dose to 0. In the current study, the results determined at 200 cm indicated a significant decrease in the radiation doses. In a study by Mariscalco et al.,[26] the exposure to radiation during minimally invasive surgery was reported to be significantly higher than during open surgery approaches. Faulkner et al.[27] reported that the use of protective glasses and neck protectors significantly reduced the problems caused by radiation exposure of sensitive organs such as the thyroid and lens. Several studies have shown that wearing a lead apron is an important protection against radiation.[11,28–32] Lead of 0.5 mm thickness has been reported to reduce radiation exposure by 97%-99%.[33]

Various studies have shown that assistants and new surgeons are exposed to more radiation than experienced specialists.[34–36] A basic measure to protect against radiation is known as ALARA (as low as reasonably achievable).[21] However, that evaluation is primarily intended for patients, and the same degree of attention is not given to the medical personnel exposed to radiation. Some studies have reported that it is possible to reduce the effects of radiation with the use of mini C-arm fluoroscopy.[19] By keeping the tube below the table, direct or disseminated radiation is contained within a limited area.[23] In the current study, imaging was completed with the tube remaining under the table. In some centers, it has been shown that the use of the PACS system (picture archiving communication system) has reduced the radiation dose.[37] Additionally, intramedullary applications made using navigation systems reduce the need for fluoroscopy.[38]

Despite various precautions, the increase in radiation-related health problems in personnel reported in research published from centers where fluoroscopy is widely used shows the need for continued research on this subject.[7,11,21] To protect the patient, surgeon, nurses, anesthesia personnel, and the entire surgical team from radiation in the orthopedic operating theater, the provision of lead-lined protection and an experienced team with a scopy technician, using a C-arm fluoroscopy, maintaining a distance of at least 150 cm, and using navigation in femoral and tibial nailing are all important.

The radiation doses determined in the orthopedic operating theater in this study were within the safe limits according to international standards. However, in addition to the risks defined to date, because of other long-term risks created by radiation—which still require research, especially at the cellular level—it is appropriate to take maximum protective precautions (lead aprons, maintaining distance), and specialized periodic training sessions should be given to orthopedic personnel on the subject of radiation risk and protection.

Conflics of Interest: No conflicts declared.

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